SOME OPPORTUNITIES FOR RESEARCH IN ENGINEERING AS APPLIED TO NORTH ATLANTIC STATES AGRICULTURE*

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The agriculture of the North Atlantic States is quite diverse. The region produces practically every crop grown in the northern United States, including small grains, corn, hay, tobacco, potatoes, truck crops, and large and small fruits. Dairying and poultry production are also quite general throughout the section and appear to be the stable and more or less basis industries. While some fairly large farms may be found, the majority of the farms of the section are medium or relatively small in size. In certain limited areas the agriculture is devoted to one or more specialities but the systems of farming usually followed are diversified rather highly.

A first-hand perspective of the important agricultural problems of the section, as indicated by the research in progress at the agricultural experiment stations, has revealed numerous instances in which engineering could participate to advantage. Attention may be drawn to the general character of a few outstanding lines.

Dairying

Dairying constitutes an important division of the agriculture of at least twelve of the thirteen States included in the section. On an average or a small scale it offers the same problems of animal nutrition, housing, feeding and breeding for production, and of handling, processing, and marketing of the products that are encountered in large scale dairying, and efficiency in the operations involved appears to be even more important.

Housing, with particular reference to maintaining the health, comfort and productiveness of the stock, and to saving time and labor in the necessary dairying operations, is perhaps the most immediate and pressing problem in dairying which should interest the engineers of the section. Several experiment stations of the section - particularly the Pennsylvania and New Hampshire Stations - have been devoting considerable of their resources to studies of the respiration and metabolism of farm animals, establishing, among other things, the conditions of temperature, humidity, air movement and the like, essential in the proper housing of dairy stock. The engineers of the section should get closely into touch with this work, and on its results, base investigations to develop new structures or to modify old structures to provide the required conditions. The durability, accessibility, and convenience of dairy barns also should be studied with the idea of minimizing the time and labor required for feeding, milking, stall cleaning, and other chores. Such studies supplemented by a consideration of the economics of the industry should aid extensively in determining the nature and extent of possible improvements. They demand a precise manipulation of the properties of structural materials and of the physics and dynamics of air movement, and call for close cooperation with dairy and agricultural economics specialists. The

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work on the development of natural draft ventilation systems, in progress at the New York Cornell Experiment Station, appears to be a proper beginning in this phase of investigation.

The proper handling and treatment of dairy products on a medium or small scale offer another important problem for engineers in the North Atlantic States. The bacteria of milk and their reaction to refrigeration and other treatments are under investigation at several experiment stations in the section, in endeavors to provide a high grade product with a minimum of treatment. The possibilities of precooling, ultra violet ray treatment, flash pasteurization with electricity, and other processes offer numerous opportunities for engineers to join hands with dairy chemists and bacteriologists in working out economical and efficient processes for treating milk. Cheap and efficient methods and equipment developed elsewhere for the sterilization of dairy utensils may be modified by engineering studies, so that they can be adapted to the type of dairying practiced in the section. Here also the work calls for close cooperation with the dairy specialists and economists, and for technical knowledge and ability.

Dairy manufacturing may be a little apart from this discussion, yet several of the experiment stations of this section are studying phases of interest to engineers. For example, the manufacture of ice cream seems to present many unsolved mechanical problems. The finding by the Maryland Station that, by the use of blades which maintain their sharpness and to which the cream mixture does not adhere, ice cream considerably improved in quality can be produced with a great saving in time and power, offers a most interesting problem in engineering physics. The solution of the problem may lie in the establishment and practical control of the physical principles governing the frictional and adhesion relations between blade materials and cream mixtures.

These few typical cases suggest that the agricultural engineers of the section should become acquainted with the dairy and animal nutrition departments of their experiment stations and identify these points of profitable contact. It seems important, however, that they also keep closely in touch with the economic aspects of the situation as influenced by the limited conditions of a diversified agriculture on a relatively medium or small scale, of which the dairying is likely to be a stable basic factor.

Poultry Production

The poultry industry of the North Atlantic States, like dairying, appears to be largely a basic feature of diversified farming and as such is widely distributed throughout the agriculture of practically every State in the region. While some of it is on a relatively large and rather specialized scale, the greater proportion of the poultry enterprises of the section are medium or small scale units. However, the problems of housing, breeding for production and disease resistance, disease control, nutrition and the like do not differ essentially from those encountered in large scale poultry production.

The housing of poultry, especially in localities where the more severe climatic conditions prevail, offers an engineering problem of immediate importance. The principles governing the air and temperature requirements of producing poultry established by the Iowa Station under controlled conditions, appear to be applicable anywhere. The engineers could well undertake the proper adaptation of these principles to local climatic conditions and materials of construc-

tion in the development of proper housing conditions for poultry. Close cooperation with the poultry specialists seems especially desirable in this work not only to adhere to already established requirements for poultry housing but in order to eliminate housing as an unknown and uncontrolled factor in the studies of poultry nutrition, breeding, production, and disease control. Since housing is known to be more or less closely linked with the control of such diseases as coocidiosis, bacillary white diarrhea, fowl pox, fowl paralysis, and blackhead, the efforts of engineers in regard to the proper housing of poultry should also be in cooperation with the animal pathologists concerned.

Certain features of poultry nutrition involve especially important problems which might offer worth while contacts for engineers. The prevention of rickets in young chicks, for example, as studied at some of the experiment stations, particularly the Pennsylvania Station, might be of interest in view of the results already obtained by the use of ultra violet light. Under the rather restricted conditions of poultry production common in the section, cheap and efficient means for natural irradiation of young poultry might be profitably developed. Doubtless this will call for both laboratory and field studies of materials for the construction of brooder and other poultry houses, which will have the necessary thermal properties and yet permit the passage of the necessary light rays. The importance of cooperation with poultry nutrition specialists in work of this character is without question. Furthermore a consideration of the value and profitableness of the industry in prevailing systems of farming in localities, as established by agricultural economists, could well supplement all this work to determine the extent to which improved conditions can be profitably obtained.

Crops

According to available statistics, the most important and widely distributed crops produced in the section are apples, potatoes, truck crops, small grain, and tobacco. Corn, hay, peaches, and small fruits also are grown in several of the States, to a greater or lesser extent, depending largely on climate, soil conditions, and topography. Pasture development and maintenance also provide a universal problem accompanying the dairying industry.

The production of the several crops involves numerous engineering problems. The more difficult and important of these perhaps, occurs in crop production under medium or small scale diversified conditions where the use of large unit labor saving equipment is economically impractical.

Apples.--Practically every agricultural experiment station in the section is conducting an extensive program of research in pomology, plant physiology, plant pathology, entomology, and economics aimed as a whole at establishing the principles governing the production, at a minimum cost, of high grade apple crops and handling and marketing them at a profit. Studies of orchard management and of the place of an apple orchard in a diversified system of agriculture are numerous, in every instance primary consideration being given to the power and labor items involved in planting, pruning, fertilization, spraying, picking, storage, packing, transportation, and shipping.

The pathological and entomological studies which are aimed at the control of scab and other apple diseases and of numerous insects injurious to the apple tree and crop, offer a wide field for profitable engineering activity. The proper projection and deposition of dusts and sprays call for the development of

spraying and dusting practices and equipment which will specifically meet the requirements for the destruction of individual insects and microscopic pests. In fact it appears that spraying and dusting so far have been largely empirical and purely mechanical practices. The tendency now is by means of laboratory studies to establish a fundamental relation between the physical properties of the surfaces of the vital organs of insects and those of the surfaces of insecticides, with the idea of developing the physical properties of the insecticides so that when properly applied they will stick and spread on the vital surfaces of insects and produce a maximum kill. In addition, the proper projection and deposition of sprays and dusts call for studies of the physics of these materials under pressure and the logical development of the mechanical principles of the apparatus required for projecting and depositing them as required. Such research calls for the coordination of the highest type of engineering skill with that of horticulturists, entomologists, pathologists, and chemists in the identification and proper manipulation of the important physical and mechanical principles involved. A striking example of this sort of work is now in progress at the New Hampshire Experiment Station and other pertinent work has been in progress at the Virginia and West Virginia Stations.

The spray residue problem in apple growing is also important from the viewpoint of the engineer. A study of the relationship between the physical properties of apple surfaces and of liquid sprays in endeavors to reduce this residue to a minimum seems a promising line of investigation. The development of methods and equipment for washing apples to remove these residues satisfactorily and economically might also be undertaken profitably by agricultural engineers in cooperation with the agricultural chemists.

Several stations are making efforts to identify the factor or factors governing winter hardiness in apple trees so that it can be reproduced artificially or intensified in apple stocks. The necessity for low temperature control in this sort of investigation calls for engineering cooperation of a very high order.

The storage problem in the apple industry, which is quite general throughout the section, appears to have many phases which remain unsolved. Physiological chemists and pathologists seem to have established rather definitely that apples cannot be stored satisfactorily with other crops without some loss, that certain rather definite temperatures and conditions of humidity are desirable for different apple varieties, and that certain storage conditions are favorable and others are unfavorable to certain of the important storage diseases of apples. There is some evidence which also points to the fact that certain types of storage destroy the vitamin potency of apples while others cause them to deteriorate generally in quality. The considerable work of this character in progress at the experiment stations in this region is establishing the bases upon which agricultural engineers can proceed to develop the desired storage structures. The Maryland Station, for example, has been active for years in determining the physiological principles of apple respiration and carbohydrate transformation in storage, facts prerequisite to the development of storages providing the proper temperatures and other conditions. Engineers also have an interesting and important problem in developing the use of cold storage to prolong the salable life of apples and in defining the limitations for its profitable adaptation. However, the development of common storages to provide the conditions of temperature, air movement, and humidity required for the satisfactory and profitable storage of apples would soom, under the circumstances, logically to precede the development of artificial

temperature control. Close cooperation by the engineers with the pomologists, pathologists, physiologists, and nutrition chemists and economists seems to be of the utmost importance in attacking this problem.

Potatoes.--The potato industry in the section, while still largely a feature of diversified farming, is rapidly becoming a specialized type of farming in some areas. Regardless of its extent, however, potato production is beset by numerous difficulties and more than half of the agricultural experiment stations in the section are engaged in agronomic, physiological, biochemical, pathological, and entomological researches aimed at the production of better and more hardy varieties and varieties resistant to diseases, at the control of diseases and injurious insects, and at the establishment of storage conditions which will prevent loss by spoilage and maintain culinary quality and nutritive value.

An analysis of the production of a potato crop has revealed that engineering is an important factor throughout from the preparation of the seed bed through the planting, fertilizing, spraying, cultivating, harvesting, storage and marketing. The opportunities for profitable participation by engineers in the agricultural researches relating to potato production, therefore, are quite extensive. The preparation of the seed bed as prescribed by potato specialists calls for the development of plowing and seed bed finishing practices and implements which will give desired results at a minimum expenditure of labor and power. Herein lie features of soil dynamics and plow design requiring a manipulation of physics and mechanics by engineers in cooperation with soil technologists. The application of fertilizers, especially some of the newer concentrated materials, offers problems of equipment design which can best be studied in cooperation with the agronomists and chemists to fully meet practical requirments.

The mechanical planting of potatoes appears never to have been perfected to the point at which the seed pieces are placed with precision at the proper depth and spacing in multiple rows. This indicates the need for studies of the physics and mechanics of taking seed pieces from bulk by moving cups or other devices to permit the uniform performance of this important operation in the precise manner prescribed and with a minimum expenditure of labor.

The cultivation of potatoes as a row crop calls now for the development of satisfactory multiple row devices for soil culture which will operate as desired without injury to the plant. The use of a general-purpose tractor in such work with suitable attachments and proper row spacing seems a promising possibility, particularly where potatoes constitute an important element of diversified farming.

The spraying and dusting of potatoes for disease and insect control has been dealt with extensively at the experiment stations, usually under the leadership of plant pathologists and entomologists. The physical and mechanical problems of properly projecting and placing sprays and dusts and the development of multiple row and other types of spraying and dusting apparatus are important engineering features of such research.

The harvesting of the potato crop, which consists of the digging, cleaning, elevating, and transportation of the tubers, is essentially a combination of engineering problems most of which have never been solved quite satisfactorily. Investigations in progress at the Pennsylvania Station are indicative of what may be accomplished by work in this subject.

The influence of storage and storage conditions on potatoes quality also has stimulated considerable research at the experiment stations. Maryland Station studies on the respiration and carbohydrate transformation of potatoes stored at different temperatures are especially illuminating in indicating the rather definite limitations of storage temperatures which will permit the maintenance of satisfactory culinary quality. Several of the northwestern stations also have indicated that storage temperature and humidity are important in the maintenance of vitamin potency in potatoes.

Since storage often appears to be an important feature in the profitable handling of a potato crop, storage structures should be developed to specifically meet the conditions prescribed by physiological chemists and pathologists for the maintenance of high quality and to minimize losses. The agricultural engineers must cooperate closely with the physiologists, nutrition chemists, and pathologists in order to make the most productive use of the principles of physics and properties of structural materials.

Truck Crops.—Practically every North Atlantic State produces truck crops to a greater or lesser extent, especially tomatoes, sweet corn, beans, peas, sweetpotatoes and other root crops, and cucurbits. Truck growing ranges from specialized operations on a large scale to average or small scale gardening constituting a feature of diversified farming. The problems of varieties, disease resistance, disease and insect control, seed bed preparation, fertilization, planting, cultivation, and spraying are more or less the same throughout the section. The regional experiment stations, practically without exception, are engaged in researches in olericulture, plant pathology, entomology, plant physiology, and soil fertility, which are aimed at the production of high quality truck crops at a minimum cost.

The tillage, fertilization and cultivation operations involved in truck crop production in a general way resemble those of potato production, although varying somewhat with the size of the enterprise and the particular crops grown. Offering the same excellent opportunity for engineering participation, they suggest the possibility of developing what might be termed small unit general-purpose machinery for tillage, fertilization and cultivation, which, by the use of different attachments, may be adapted to the needs of several truck crops and also potatoes. The development of the small general-purpose tractor might also be promising in this connection, especially on the average or small scale diversified farms. The Pennsylvania and Massachusetts Experiment Stations have indicated the possibilities of investigations along this general line.

Most truck crops appear to be planted largely by hand, especially when grown on limited areas, while the operation may vary quite widely with the different crops, the development of small unit general-purpose planters and seeders with seeding attachments for different crops might be an interesting and profitable possibility for saving labor in planting some crops at least.

The diseases of truck crops are numerous and varied and many of the types and kinds of treatment used in their control involve engineering features. The Delaware Station found that the control of tomato root rot, for example, calls for the development of spraying and dusting methods and equipment as well as for special cultural practices. The control of downy mildew and leaf blight of cucurbits calls for seed disinfection requiring the development of suitable equip-

ment. The studies of bean anthracnose by the Maryland Station show that the disease is spread by cultivating machinery. Indeed they suggest that it may be possible to prevent such spread by modification of the machines themselves. Thus the control of truck diseases is bristling with engineering problems, suggesting the importance of a joint attack by agricultural engineers with plant pathologists.

The control of insects injurious to truck crops presents a rather similar situation. At several of the experiment stations the investigations on the corn ear worm, the Mexican bean beetle, and the potato tuber moth, for example, point to the necessity for spraying and dusting practices which have obvious engineering features.

The storage of certain root truck crops such as beets, turnips, carrots, and parsnips offers problems which in general resemble those of the apple and potato although differing specifically. The Maryland Station, for example, in studying the respiration and carbohydrate transformation of such crops in storage has observed that the keeping of each of these crops presents a special problem. Consequently the engineer should know the individual requirements of each crop before attempting to develop a suitable storage.

From the foregoing statements it seems evident that the truck crops situation in the section offers excellent opportunities for profitable engineering participation in the researches on the subject in the experiment stations, and the logical procedure appears to be direct cooperation with the agricultural specialists concerned.

Field Crops

Tobacco.--Tobacco production in the North Atlantic States is confined largely to about seven States, including Virginia, West Virginia, Maryland, Pennsylvania, Connecticut, New York, and Massachusetts, and the experiment stations of these States are conducting agronomic, physiological, pathological, entomological, and soil fertility studies aimed at the production of high quality tobaccoes at a minimum cost. Tobacco production in these States varies from large to small scale enterprises and presents numerous problems of tillage, cultivation, fertilization, disease and insect control, harvesting, curing, and marketing in which the engineers might profitably become interested.

The opportunity for developing small unit general-purpose tractors and tillage, fertilization and cultivating machinery seems to be an especially promising possibility. The storage and curing seem to raise a question as to the proper construction of tobacco curing barns. This in turn suggests that the agricultural engineers might well cooperate with the tobacco specialists in establishing the principles of tobacco-curing barn design.

The investigations at the stations on the control of diseases and insects are also quite extensive and several point to the need for spraying and dusting practices which have obvious engineering features.

Corn.--More than half the States in the section produce some corn, usually however, as a feature of diversified farming. The experiment stations concerned are naturally interested in researches to produce better and hardier strains of corn and to determine means of combating diseases and insect pests.

The European corn borer is a problem of some magnitude in several of the corn growing localities, and entomological and agronomic researches to combat this pest are in progress. The part which engineers can take in this work has been well outlined elsewhere and it need not be repeated.

The tillage, fertilization, planting, cultivation and harvesting of corn all offer opportunities for engineering participation with particular reference to the development of labor-saving methods and equipment. Here again largely on account of the diversified medium scale farming of the section, the development of small unit general-purpose tractors and machines for tillage, planting, fertilization, cultivation and harvesting might be profitable. The harvesting operation especially seems susceptible of modification through the development of multiple-purpose labor-saving machinery which might, for example, harvest and cut into silage at the same time. Cooperation by the engineers with the agronomists seems quite desirable in such investigations.

Small Grains.--More than half of the States in the section produce some small grains, principally wheat and oats, usually as features of diversified farming. Some soybeans are also grown and for the purpose of the present discussion will be considered along with the small grains.

The researches in progress at the experiment stations, especially with wheat, are concerned with breeding for hardiness, disease resistance and other qualities, disease and insect pest control, planting, fertilization, harvesting, storage, and artificial drying, most of which offer excellent opportunities for agricultural engineering participation.

Studies in the section on the combine, for example, have raised questions as to the adaptability of this machine to the conditions encountered. In this connection the development of a small general-purpose combine for harvesting the relatively limited grain crops appears to be an interesting possibility. Such a machine would need to be adaptable to all the small grains and beans grown perhaps by the use of different cylinder and concave attachments. It might even handle the corn crop, since the feasibility of this has been demonstrated already at the Iowa Station.

Grain drying also offers an opportunity for engineering activity. It is important that the mechanism of drying under controlled conditions be determined first to provide a sound fundamental basis for the development of practical methods and equipment. Naturally such work should be conducted in cooperation with agronomists and probably also with cereal chemists.

Organization of a Project

Attention has been called above to a few of the outstanding opportunities for engineers to participate in the solution of some of the more important problems confronting the agriculture of the North Atlantic States. Some of the more important points in the organization and planning of a project of engineering investigation, based upon the requirements for engineering participation advanced by one of the above agricultural problems, may be of interest. For illustration, a project already in progress in one of the agricultural experiment stations of the section will be discussed. No attempt will be made, however, to adhere to exact titles or procedure.

For the records of the agricultural engineering department let it be as-

sumed that the project is entitled "The Fundamental Development of a Portable Small Grain Drier. The historical background for the project goes back several years to a finding by farm management studies that the power and labor expenditure in the production of a wheat crop constituted an overwhelmingly excessive proportion of the total cost. Efforts to lower these items by engineering precedure led into the adaptation of the combining practice in cooperation with agronomists and economists. These studies revealed defects in the combining practice which, while apparently saving labor, produced wheat which would not stand storage and was penalized on the market. The necessity for producing a completely cured wheat of superior quality by the new efficiency methods thus became evident. Further studies showed that in order to be practicable the process and equipment for curing should accompany the combine in the field. Thus a rather definite requirment was developed for a small portable grain drying apparatus which would produce cured wheat meeting the quality requirments of the agronomist and cereal chemist. The very nature of the requirement precluded the possibility of completely solving the problem by the mere testing of available drying equipment. It was necessary to establish the principles governing the mechanism of the removal of moisture from wheat in order that the process might be controlled and manipulated with precision to meet the requirments indicated by the agronomist or cereal chemist for any wheat. It was realized that once the mechanism of moisture removal from wheat by artificial means was known it could be duplicated and controlled at will under any conditions and accurate specifications for portable equipment to perform the drying could be laid down.

The organization of the study thus calls for a triple cooperation. The cereal chemist and milling expert are to establish a measure for quality in combined wheat, and the agronomist is to determine what moisture content in combined wheat corresponds to this measure of quality not only with reference to storage and nutritive quality but also germinating capacity. The engineer is to establish under controlled laboratory conditions the mechanism of producing a wheat of the proper moisture content without destroying the other named qualities. From this knowledge standards for comparison will be available for use in tests of available drying equipment. If not already available, equipment which fully meets the requirements will be developed.

Thus an agricultural engineering project is evolved which calls for a precise manipulation of physics, mechanics, and thermodynamics, which is based on a very definite agricultural requirment, and which calls for a coordination of agricultural engineering effort with the activities of the several agricultural specialists concerned.

Conclusion

The above brief review of agricultural research in the North Atlantic States indicates numerous points of profitable contact for agricultural engineering, many of which are rather peculiar to the section owing to the prevalence of medium to small farming units and diversified practices. It does not appear particularly necessary for agricultural engineers to look beyond the existing programs of research in their own experiment stations to find opportunities for profitable research activity. Therefore, the engineers should become fully acquainted with those programs and the agricultural specialists in charge in order to identify the most profitable pointsof contact and conduct investigations of these features on a fully cooperative basis.

The nature of some of the contacts noted also emphasizes the fact that constructive participation by engineers in much of the agricultural research will demand considerably more than mechanical skill. A knowledge of and ability to use advanced physics, mechanics, thermodynamics, and kinematics seem necessary in many instances to cope with the problems encountered. Advanced training in physics seems especially desirable in this work and this is in keeping with the requirements of other industries.